

Comparison of 2D and 3D displays and sensor fusion for threat detection, surveillance, and telepresence

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ABSTRACT

Visible, infrared (IR) and sensor-fused imagery of scenes that contain occluded camouflaged threats are compared on a two dimensional (2D) display and a three dimensional (3D) display. A 3D display is compared alongside a 2D monitor for hit and miss differences in the probability of detection of objects. Response times are also measured. Image fusion is achieved using a Gaussian Laplacian pyramidal approach with wavelets for edge enhancement. Detecting potential threats that are camouflaged or difficult to see is important not only for military acquisition problems but, also for crowd surveillance as well as tactical use such as on border patrols. Imaging and display technologies that take advantage of 3D and sensor fusion will be discussed.

1. INTRODUCTION

Computer driven interactive 3D imaging has made significant progress during the past decade and 3D display technology continues to develop rapidly. One of the important applications of this technology is an interactive tool for vehicle design. The Zebra Imaging Company in Austin, Texas investigates technical feasibility of developing such a toolset using a holoprinter and integral imaging concepts. The largest in the world hologram of a Ford car, which was generated by Zebra Imaging using a holoprinter, was displayed at the Detroit Autoshow in 1998-1999. The size of this hologram was 6' x 4'. The disadvantage of this holoprinter was its slow speed. It took several days to print out a computer generated hologram (CGH) of a vehicle. The Zebra Imaging was utilizing a CAD image of a Ford vehicle as an input for CGH. Defense Evaluation and Research Agency (DERA) in the UK is developing a 3D display for vehicle design, which is interactive in real time. It is based on computer generated Fourier holograms (CGFH). DERA is implementing a high-resolution LCD as an output device for an interactive in real time volumetric image of a vehicle. The drawback of the 3D holographic real time display was its computational intensity. The computation of CGFH of a 3D object with outside dimensions of 2" x 2" x 2", its coding and reconstruction in real time required 20 billion computations. An alternative approach is a stereoscopic display, utilizing a 3D CAD package as an input image, for example, IcemSurf, implemented by Ford Motor Company. A haptic interface is used for an output image for working in 3D. This image can be viewed using stereoscopic glasses or a heads-up display. The review of the 3D imaging technologies can be found in the reference work by McCallister [1].

The Visual Perception Laboratory (VPL) at TACOM is interested in exploring various display technologies for applications having to do with camouflage assessment of military vehicles, non-destructive testing, medical telepresence and homeland defense. The realism and depth perception provided by 3D displays is important to photo simulation tests having to do with camouflage because it is important to know how close combat vehicles can get to the enemy without being detected. At present, the TARDEC VPL has a 180-degree wrap around screen and three high resolution projectors that provide imagery with pixels that subtend less than 1 arc second at 15 to 16 feet from the screen. The VPL team is interested in implementing new 3D display technologies with improved resolution and color fidelity.

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The authors were able to overcome some difficulties associated with holographic displays and the inconvenience of using stereoscopic glasses or heads-up display, by implementing an autostereoscopic display system, VIS4D™, developed by Ethereal Technologies, Inc., of Ann Arbor, Michigan. The core component of this system, an optical platform (Figure 3), is complemented by Stretchable Membrane Mirror (SMM) technology [2] developed at the University of Strathclyde in Glasgow, Scotland. This large format, light weight, variable focal length mirror is a cheap alternative to conventional fixed-curvature, heavy weight, expensive glass based optics. [2].

2. EXPERIMENTAL PROCEDURE

Fourteen civilian subjects were picked randomly from the employee population at TARDEC. Each subject took both the 2D test and 3D test. Which test they took first was determined by a random number generator. The subjects were then evaluated to verify if they could experience stereopsis, and were also shown how to use the VIS4D workstation. They were shown how to align themselves by using a rangefinder made-up of two orange disks placed at the top of mirror assembly. They were shown stereo pairs and asked to verify they could see a 3D image. Once they were comfortable with the overall environment the test began.

The photo simulation test consisted of ten images in a random order. The 2D and 3D test had the same images, albeit the 3D test used stereo pairs. The 2D test was done on a flat panel monitor and the 3D test was done on the VIS4D workstation. Each image had four objects defined and labeled A, B, C, and D. The purpose of the test was to determine the relative order of the four objects from closest through the farthest starting with the closest object and ending with the farthest object. There was no time limit, but it took the subjects about 5 – 10 minutes to take the test. Response time was measured during the test for each subject and each target in the image.

Figs. 1, 2, and 3 below show various details of the VIS4D workstation. In Fig. 1, one can see that the footprint mirror assembly is 2.7 M x 1.6 M and the height of the mirror assembly is also 1.6 M. The image occupies most the field of view of a subject. The larger viewing format assists through the augmented reality effect of immersion that an observer can experience while using system.

Fig. 2 below shows the workstation desk that is 1.5 M from the front of the display. The desk provides a comfortable place for the user to work and make decisions.

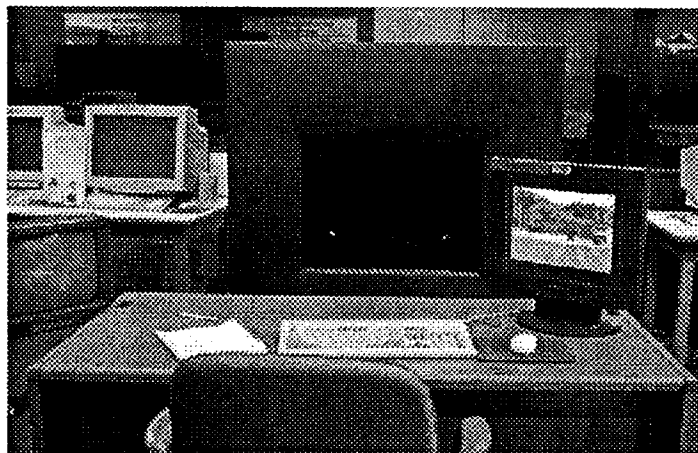


Fig. 1: VIS4D™ system with desk

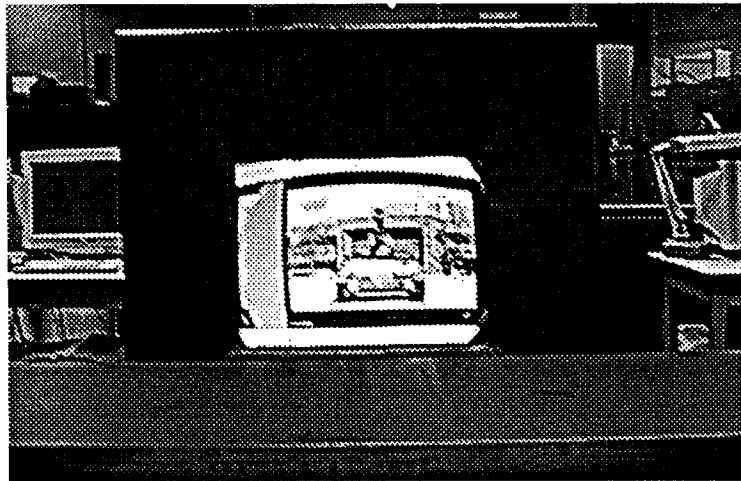


Fig. 2: Real image of tank as projected from the mirror

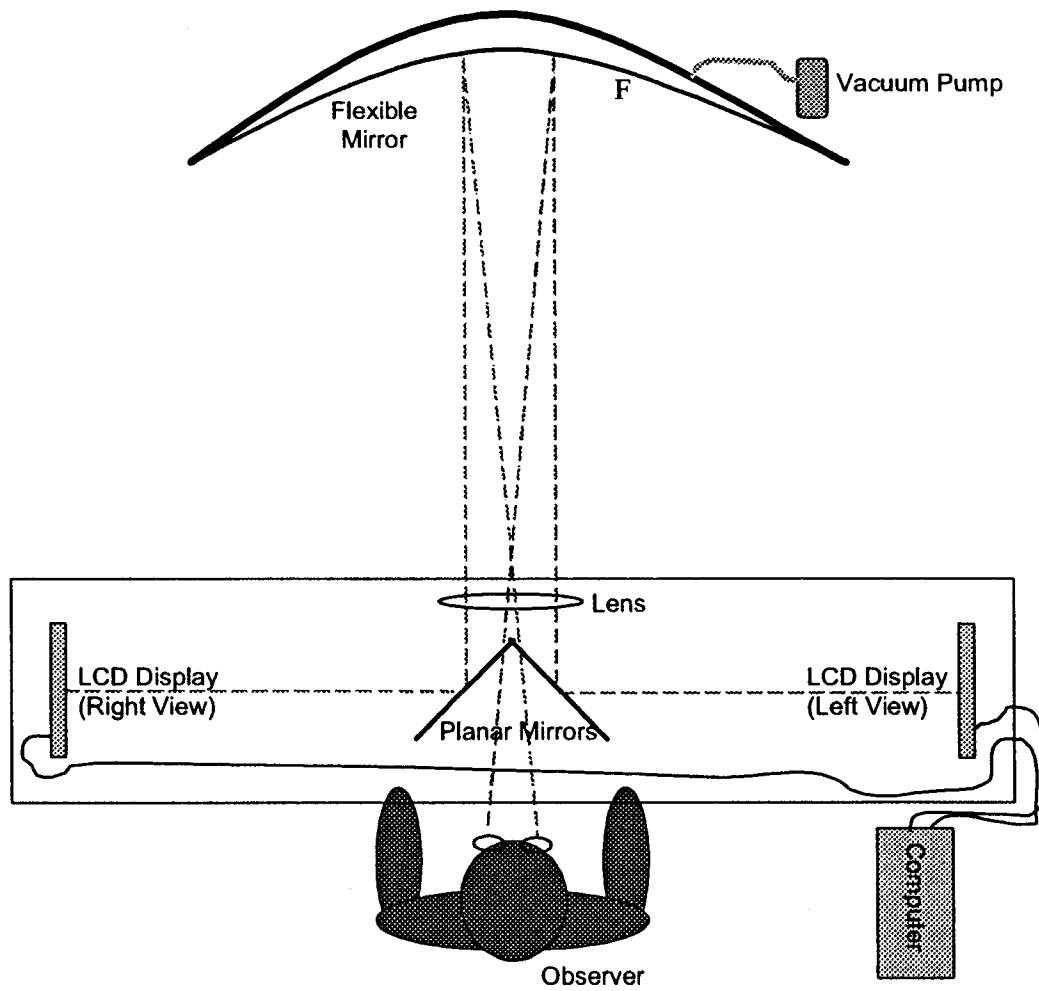


Fig. 3: Schematic of optical platform with SMM

3. THE UTILITY VOLUMETRIC DISPLAYS

Cognitive systems represent a new rapidly developing area of technology. The term cognitive system is referring to systems and processes similar to the human mind such as understanding, reasoning, judgment, memory and learning. Joint cognitive systems combine computer and human system components contributing to the performance of system cognitive functions. Information design can influence the nature of communication through the form of presentation of displayed information. Cognitive displays facilitate information presentation through organization in relation to the tasks to be performed. Cognitive imagery displays can present the appearance of a 3D electronic window of the world to make the imagery more intuitive, cognitively compatible, and immediately task relevant. This can include functions such as electronic cueing and highlighting of camouflaged, hidden or partially obscured objects. The objects of interest can be determined directly from the visual scene. Automated target recognition (ATR) function can be implemented with image processing and displays.

A display can be defined as a structured and purposive presentation of information to the human senses [Stokes, Wickens & Kite, 1990]. The function of a display is to support a user in achieving an objective by providing essential information. Displays may access more information than is available to direct observation by an operator. The limits of an operator's cognitive resources constrain the level of performance that can be achieved.

Perception has been defined as the functional transformation of sensory data into Situational Awareness (SA). SA describes the perception of elements in an environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. Spatial awareness is an important component of SA. It is an operator's perceptual and cognitive comprehension of the 3D geometry of the environment in which he or she is operating. [3]

It is important to mention some advantages and disadvantages of the implementation of 3D displays. Three-dimensional displays provide more natural representation of the visual scene of the real world; they reduce the need for mental integration of information from multiple sources. Tasks in which spatial awareness is critical may be facilitated by the use of 3D technology. The disadvantages of 3D representation are: it can effect the viewer's ability to make precise judgments on each dimension alone; it creates some ambiguity regarding the precise location of objects along the line of sight. In other words, small artifacts in the design of the mirror can potentially cause some ambiguity. These factors should be taken into consideration while making a decision in selecting a display system.

4. DATA

Fig. 4 below shows the task the viewers were given, namely, to determine the relative range of the targets in the image using the 2D monitor and the 3D display. The vehicles were labeled A,B,C, and D and subjects were asked to rank the vehicles according to increasing range. The baseline from which distance is determined is the curb in the image.

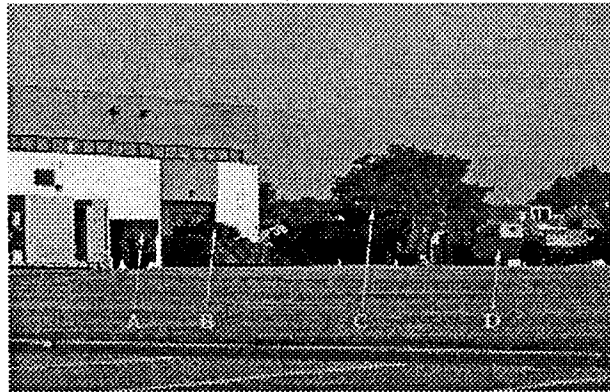


Fig. 4: Example image from the test

Test Data Analysis

The chart below in Fig. 5 shows the number of correct responses for all subjects summed over all pictures. The graph shows that the performance is highly dependent on the subject. This difference may in part be due to the need of the subjects to situate themselves in the eyebox.

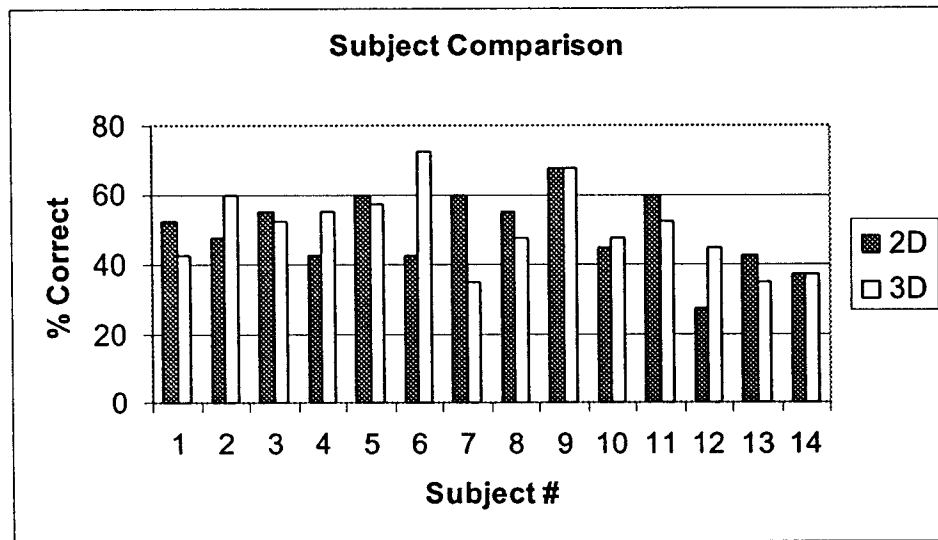


Fig. 5: Overall response time for 2D versus 3D displays

STATISTICAL ANALYSIS

We are interested in determining whether viewing outdoor scenes with a 3-D display improves depth perception over viewing the same outdoor scene with a 2-D display. Each subject was shown ten outdoor scenes in a random order and asked to rank four targets from closest to farthest. The percentage of correct responses was recorded.

Since subjects differ in their perception skills, we shall use them as blocks. Once a subject is chosen, the order in which type of display is presented is randomly determined. There was a several week interval between tests to eliminate any learning from the first test. Thus, we have a randomized complete block design. The complete analysis variance for this experiment is summarized in Table 1. Both DISPLAY and SUBJECT are not significant. Thus, we conclude that the display type does not affect the subject's score and that there is not a significant difference between subjects.

Tests of Between-Subjects Effects

Dependent Variable: SCORE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2020.982 ^a	14	144.356	1.551	.218
Intercept	70250.223	1	70250.223	754.727	.000
SUBJECT	2015.402	13	155.031	1.666	.185
DISPLAY	5.580	1	5.580	.060	.810
Error	1210.045	13	93.080		
Total	73481.250	28			
Corrected Total	3231.027	27			

a. R Squared = .625 (Adjusted R Squared = .222)

Table 1: ANOVA for 2D versus 3D test

The plot below shows that there is virtually no difference in the median of the scores for 2D versus 3D test.

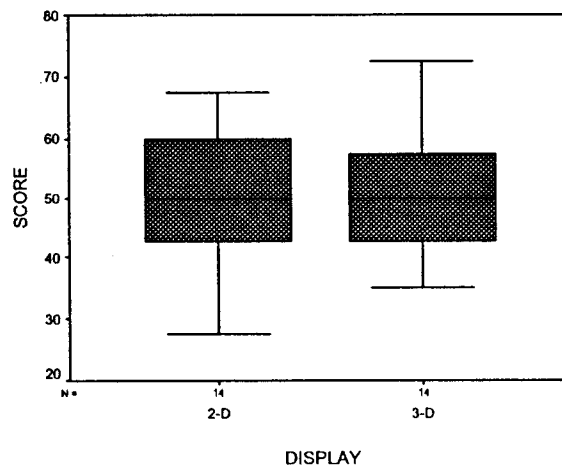


Fig. 6: Plot showing medians of score versus display

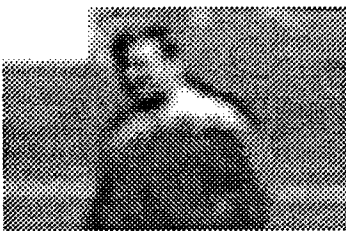


Fig. 11: visible image

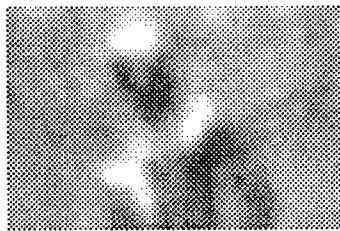


Fig. 12: millimeter wave image³

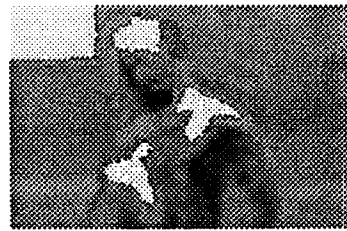


Fig.13: fused image

A 3D display could also be applied to crowd surveillance and screening at public access points. The images above in Fig.'s 11, 12, and 13, are the visual, passive millimeter wave [3], and fused images respectively of a man with a concealed weapon. In these times of increased concern about terrorists and passengers carrying concealed weapons, sensor fusion and 3D displays could be of benefit in alerting guards to potential problem passengers. Combining the sensor fusion with a 3D display could also improve the recognition rate of guards using cameras that scan crowds for people that are listed in a known terrorist database.

CONCLUSIONS

The authors performed a test in which the response time and the number of correct decisions on the relative range of many targets is compared for a 2D versus 3D display. The authors found that the recorded response time was greater using the 3D display, and there was no significant difference in the number of correct target identifications for this data set, in the 2D versus 3D display. Training and experience using the mirror may have had an impact on the performance of the subjects, although, the test monitors tried to be consistent in this regard. Another factor that may have influenced the test was the degree of 3D perspective in the images that were used for the test. It should be noted that when people view demonstrations in the laboratory, there is agreement that a true 3D image can be seen in the mirror.

Given this was the first attempt to compare 2D versus 3D here at TARDEC, this was a learning experience. Images within the stereo pairs contained alignment and nomenclature problems that effected stereopsis experienced by the subjects, as reflected in the statistics. Subsequent test are planned where these issues will be addressed and corrected.

Future areas for research include testing the VIS4D workstation in remote telemedicine applications and non-destructive material testing using volumetric imaging technologies.

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